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Physics 123 Quiz #2, October 2, 2006

1. 200g of gold is heated to a temperature of 200°C and then is placed in a thermally insulated beaker containing 50g of water at 20°C. The water temperature rises to 39.7°C and remains there. What is the specific heat of gold, if the specific heat of water c_{water} = 4190 J/Kkg?

$$\Delta E_{thermal} = 0 = Q_{Au} + Q_{water} \rightarrow Q_{Au} = -Q_{water}$$

$$m_{Au} c_{Au} \Delta T_{Au} = -m_{water} c_{water} \Delta T_{water}$$

$$c_{Au} = \frac{-m_{water} c_{water} \Delta T_{water}}{m_{Au} \Delta T_{Au}} = \frac{-50g \times 4190 \frac{J}{kg\times K} \times \left(39.7^\circ C - 20^\circ C\right)}{200g \times \left(39.7^\circ C - 200^\circ C\right)} = 128.7 \frac{J}{kg\times K}$$

2. 100g of diatomic oxygen, O_2, is distilled into an evacuated container whose volume is 600 cm^3. If the temperature of the gas is 150°C, what is the pressure of the gas? (Hint: The atomic mass of O is 16 amu, where, 1 amu = 1.66x10^{-27} kg.)

$$PV = nRT \rightarrow P = \frac{nRT}{V} = \frac{3.13mol \times 8.31 \frac{J}{mol\times K} \times 423K}{600cm^3 \times \frac{1m^3}{(100cm)^3}} = 1.83\times 10^7 \frac{N}{m^2},$$

$$\text{where, } n = \frac{N}{N_A} = \frac{\left[0.1kg \big/ \left(32\times 1.66\times 10^{-27} kg\right)\right]}{6.02\times 10^{23} \frac{molecules}{mole}} = 3.13 mole.$$

3. It is possible to "cool" atoms by letting them interact with a laser beam under proper, carefully controlled conditions. Laser cooling is currently a subject of intense research activity, and it is now possible to cool a dilute gas of atoms to a temperature of less than one *micro*kelvin. The atoms are kept from solidifying by their extremely low density. (For more information on laser cooling, you are encouraged to talk to Prof. Orzel.) What is the speed of a cesium atom at a temperature of 1 μK, if the mass of a cesium atom is 2.21x10^{-25} kg?

$$\tfrac{1}{2} m\langle v^2\rangle = \tfrac{3}{2} k_B T \rightarrow \langle v\rangle = \sqrt{\frac{3k_B T}{m}} = \sqrt{\frac{3\times 1.38\times 10^{-23} \frac{J}{K} \times 1\times 10^{-6} K}{2.21\times 10^{-25} kg}} = 0.014 \frac{m}{s} = 1.4 \frac{cm}{s}$$

Useful Equations and Constants

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\theta_i = \theta_r$$

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

$$n = \frac{c}{v}$$

$$PV = Nk_BT = nRT$$

$$\tfrac{1}{2}mv_{avg}^2 = \tfrac{3}{2}k_BT$$

$$Q = mc\Delta T$$

$$Q_{Total} = \sum_{i=1}^{p} Q_i$$

$$\Delta E_{th} = Q + W$$

$$W = -\int PdV$$

$$PV^{\gamma} = TV^{\gamma-1} = \text{constant}$$

$$\mathrm{C_P} = \mathrm{C_V} + \mathrm{R}$$

$$k_B = 1.38\times10^{-23}\,\tfrac{J}{K}$$

$$R = 8.31\,\tfrac{J}{mol\times K}$$

$$N_A = 6.02\times10^{23}$$

$$C_V = \tfrac{3}{2}R$$

$$P_{air} = 1atm = 1.103\times10^5\,Pa$$

$$T(K) = T(^oC) + 273$$

$$g = 9.81\,\tfrac{m}{s^2}$$

$$c = 3\times10^8\,\tfrac{m}{s}$$